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B71 01017

SUBJECT: Sonic Boom Considerations in Selection of a Site for Space Shuttle Operations - Case 900

DATE: January 11, 1971

FROM: J. E. Johnson

ABSTRACT

Sonic boom effects will be a factor in the choice of a launch and recovery site for the Space Shuttle. The maximum boom intensity associated with Shuttle operations is likely to be somewhat greater than is anticipated for supersonic transport operations. However, the relative infrequency of shuttle flights and the limited land areas to be overflown should render the boom effects tolerable. Three consolidated launch and recovery operations center locations are considered - Edwards AFB, Calif., Holloman AFB, N.M., and Cape Kennedy, Fla. The relative desirability of these sites from the viewpoint of minimizing the population exposed to sonic boom depends upon the launch and recovery azimuths to be flown.

(NASA-CR-116949) SONIC BOOM CONSIDERATIONS IN SELECTION OF A SITE FOR SPACE SHUTTLE OPERATIONS (Bellcomm, Inc.) 7 p

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MEMORANDUM FOR FILE

Sonic booms will be inherent in Space Shuttle operations. The intensities of the booms cannot be predicted at this time, but the peak amplitudes for both Booster and Orbiter will probably exceed the approximately 2.0 pounds per square foot (psf) average incremental pressure estimated to occur directly underneath the flight path of a supersonic transport (SST) in level cruise at 70,000 ft. (Ref. 1). The geometry of the shock waves associated with sonic boom is illustrated in Fig. 1.

Some of the factors affecting the magnitude of the sonic boom are: (Refs. 2 & 3)

Mach number - Boom intensity increases slowly with Mach number (M), which is the ratio of vehicle velocity to the local speed of sound; the increase is proportional to

$(M^2-1)^{\frac{1}{8}}$. Thus, at Mach 10 the boom will be 55% more intense than at Mach 2.

Altitude - The boom intensity decreases with increasing altitude, theoretically with the three-quarters power of the altitude. However, the width of the boom corridor on the ground increases with altitude.

Vehicle Configuration - Aerodynamically streamlined vehicles create a less intense sonic boom. The ratio of vehicle length to body diameter is the key factor. For an SST this value is about 20, for the Booster and Orbiter about 6 to 8.

Angle-of-Attack - A high angle-of-attack, since it presents a larger cross-section area to the atmosphere, will generate a more intense boom.

Relative to an SST, only the altitude factor will tend to reduce the Shuttle boom, the others will tend to increase it.

The value of sudden pressure differential ("boom") that begins to be objectionable to people on the ground depends upon many subjective variables, but generally has been shown to be about 1.0 psf. Minor structural damage (such as broken unreinforced glass, falling of loose plaster, etc.) begins to occur at around 2.0 psf. Major damage to reasonably well-built structures does not appear to become significant until at least 10 psf. (Ref. 1).

Although the boom intensity from both Shuttle stages may peak at over 2.0 psf, there are some mitigating factors:

- The shock wave envelope of the sonic boom (Fig. 1) is conically-shaped with a vertex half-angle $\theta = \sin^{-1}(\frac{1}{M})$, and is centered on the velocity vector. As long as the flight path angle γ during descent is greater than θ, the shock wave cone will not intersect the ground, and no boom will be heard. This will generally be the case when the Shuttle vehicles operate at high angle-of-attack. (For example, above Mach 5 a descent angle of 12° or greater will produce a shock wave cone that will not intersect the ground).
- The peak pressure will occur directly under the flight path. The boom intensity will fall off at right angles to the flight path. No boom will be heard outside the cone.
- In contrast to SST operations, Shuttle flights will be infrequent and the length of sonic boom path per flight will probably be shorter.

The relative desirability from a sonic boom viewpoint of three candidate Shuttle operations sites appears as follows:

Edwards AFB, California. Launches to the northeast would overfly desolate, sparsely populated areas. Launches to the southeast for inclinations up to 55° (the Space Station inclination) would also overfly sparsely populated areas. Most of the reentry ground tracks would fall over the Pacific. Reentries from 55° inclination orbits would pass near either the San Francisco area (about 300 nm away) or the Los Angeles area (about 70 nm away).

Holloman. Launches to both the northeast and the southeast would not overfly major population areas. Returns from orbit to the northeast could pass over or near El Paso (about 70 nm). Returns to the southeast would overfly a large area of the western U. S., although the 55° inclination track falls almost entirely over sparsely populated regions.

Cape Kennedy. Launches to both the northeast and southeast would be over the Atlantic. Returns to the northeast would overfly a small stretch of Mexico, the Gulf of Mexico, and relatively inhabited regions of Florida. Returns to the southeast would overfly a long stretch of the U. S. from northwest to southeast, including several population centers, and would be undesirable.

From the viewpoint of avoiding sonic booms over populated areas, there appears no clear-cut choice among the three candidate sites. Each location has specific advantages and disadvantages. In general, the relatively low mission frequency should not make sonic booms a significant problem for the Shuttle.

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Attachment
Fig. 1

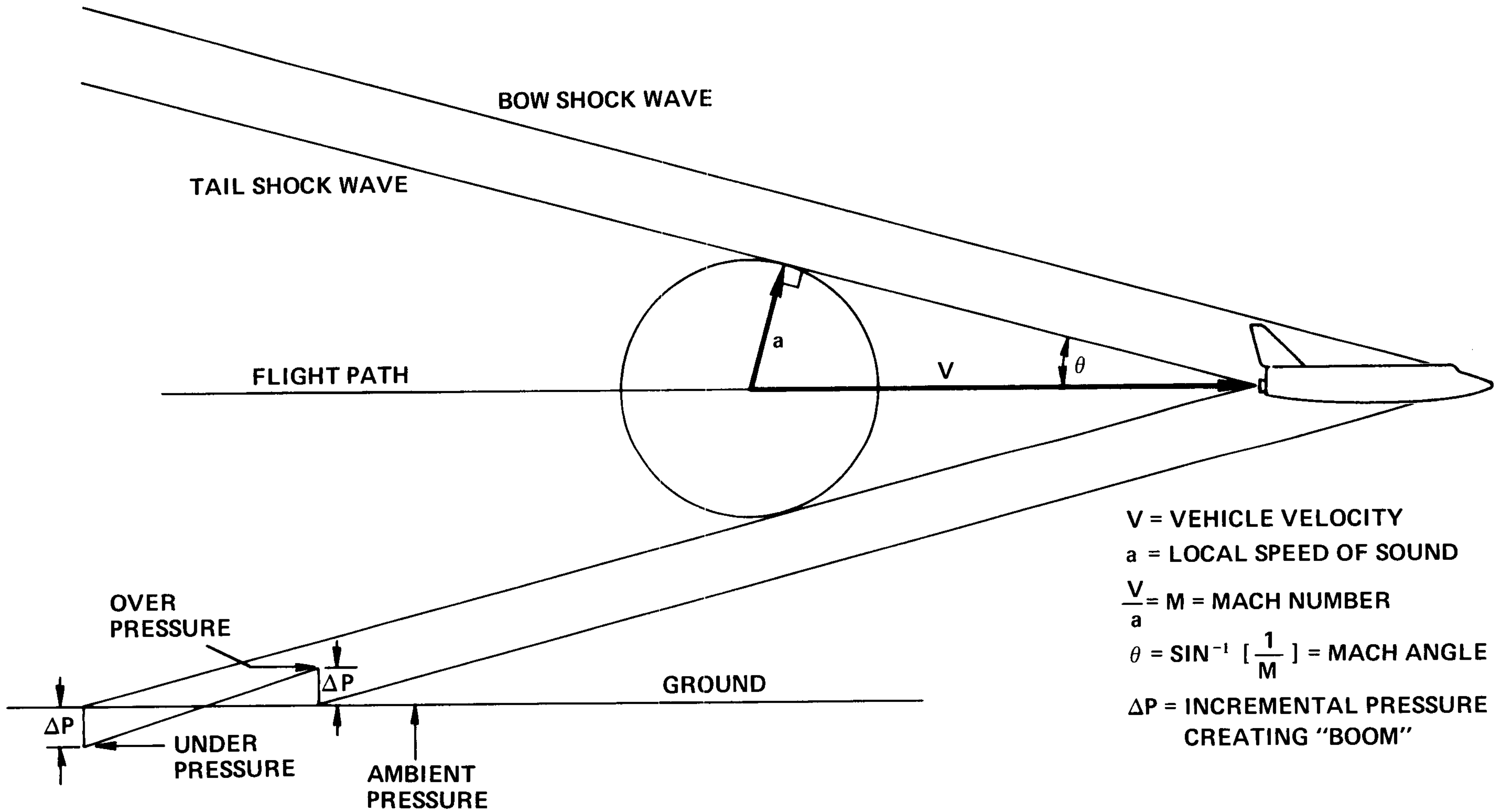

FIGURE 1 - SONIC BOOM GEOMETRY

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